Evaluation of Antioxidant Effects and Sensory Attributes of Chinese 5-Spice Ingredients in Cooked Ground Beef

SAUMYA DWIVEDI, MIHIR N. VASAVADA, AND DAREN CORNFORTH

ABSTRACT: This study determined antioxidant and sensory characteristics of cinnamon, cloves, fennel, pepper, and star anise (Chinese 5-spice ingredients) in cooked ground beef. Total aerobic plate counts were also measured. Mean thiobarbituric acid (TBA) values were high (3.4 ppm) for control cooked ground beef samples. With 1% use level, all spice treatments had lower pooled mean TBA values than controls. At the lowest use level of 0.1% of meat weight, all spices except pepper had lower TBA values than controls. Treatments with 0.1% cloves had lower (P < 0.05) TBA values than 0.1% levels of other individual spices. Star anise, fennel, pepper, and cinnamon samples at 0.5% use level had lower mean TBA values than controls, but not different from 1.0% levels, respectively. Thus, the lowest effective spice level for cloves was 0.1% and 0.5% for the other spices. There was a high correlation (r < 0.01) between TBA values and panel scores for rancid odor and flavor (0.83 and 0.78, respectively). Spice flavor was inversely correlated (P < 0.01) with rancid odor and flavor (−0.57 and −0.61, respectively). The 5-spice blends did not affect microbial load of cooked samples compared with controls. In conclusion, all spices and blends had a dual effect, reducing rancid odor/flavor and imparting a distinctive flavor to cooked ground beef.

Keywords: Chinese 5-spice, antioxidant, ground beef

Introduction

The Chinese conceptualized the theory of “5 Elements” under which everything in our surroundings could be categorized into 5 basic elements. Chinese 5-spice is 1 application of the 5 elements theory. It was developed in an attempt to produce a powder that encompassed the 5 flavor elements: sweet, salty, sour, pungent, and bitter (Needham and Wang 1956). The traditional 5-spice mixture includes cinnamon, cloves, fennel, Szechwan pepper, and star anise. Today, however, Chinese 5-spice may also include ginger and nutmeg and can be easily obtained in any Asian market.

Lipid oxidation is 1 of the major causes of food deterioration. Lipid oxidation may also decrease nutritional value by forming potentially toxic products during cooking and processing (Shahidi and others 1992; Maillard and others 1996). Warmed-over flavor (WOF) is associated with cooked meat and intensifies during refrigerated storage (Tims and Watts 1958). Heating temperature affects the extent of lipid oxidation (Keller and Kinsella 1973). Ferric and ferrous iron ions catalyze the decomposition of lipid peroxides to more volatile aldehydes and ketones (McDonald and Hultin 1987). Early work showed that the meat pigment myoglobin had little or no catalytic effect on lipid oxidation in simple model systems or red meats (Sato and Hegarty 1971; Love and Pearson 1974). However, more recent work has shown lipid oxidation catalyzed by oxidized myoglobin species (Reeder and Wilson 2001), hemoglobin in fish muscle (Richards and Hultin 2002), and heme derived from myoglobin oxidation (Baron and Andersen 2002).

Compounds with antioxidant properties have been found in spices, oil seeds, citrus pulp and peel, and in products that have been heated and/or have undergone non-enzymatic browning. In addition to imparting distinctive flavors, spices contain antioxidant properties and inhibit rancid flavor development associated with lipid oxidation (Chipault and others 1952, 1955; Namiki 1990). Spices such as cloves, cinnamon, turmeric, black pepper, ginger, garlic, and onions exhibit antioxidant properties in different food systems (You-nathan and others 1980; Al-Jalay and others 1987; Jurdi-Haldeman and others 1987). Spices have antioxidant properties due to the presence of compounds such as flavanoids, terpenoids, lignans, and polyphenolics (Craig 1999). However, their use may be limited in some foods due to their characteristic flavor and aroma. Use of unsterilized spices and herbs also increases the possibility of bacterial contamination in high-moisture foods (Garica and others 2001).

Antioxidant compounds have been identified in all 5 components of Chinese 5-spice. Anise (Pimpinella anisum L.), nutmeg, and licorice all had strong hydroxy radical (OH-) scavenging activity in deoxyribose assay (Murcia and others 2004). Fennel (Foeniculum vulgare) has in vitro antioxidant activity (Okty and others 2003). The antioxidant compounds in fennel include 3-cafeoylquinic acid, rosamirinic acid, and quercetin-3-O-galactoside (Parejo and others 2004). Cloves (Syzygium aromaticum) contain eugenol and eugenyl acetate as the major aroma constituents.

Both compounds inhibit hexanal formation (a product of lipid oxidation) in cod liver oil (Lee and Shibamoto 2001). Antioxidant activity in pepper (Capsicum annum) is due to presence of ascorbic acid, flavonoids, capsaicinoids, and phenolic acids (Jimenez and others 2003). Cinnamic aldehyde in cinnamon (Cinnamomum zeylanicum) has potential antioxidant properties. Cinnamon and mint exhibited higher antioxidant properties than anise, ginger, licorice, nutmeg, or vanilla in a lipid peroxidation assay (Murcia and others 2004). A concentration of 500 μg/mL cinnamon extract inhibited hexanal production by 5% (Lee and Shibamoto 2002).
Although the components of Chinese 5-spice have been shown to have antioxidant activity in model systems, our objective was to determine the optimum level of each spice for antioxidant properties in cooked ground beef. Sensory evaluation was also done on cooked ground beef containing various spices at their optimum (lowest effective) antioxidant level.

**Materials and Methods**

**Experiment 1—Thiobarbituric acid (TBA) assay**

The experiment was a completely randomized block design with 6 ground beef treatments (cinnamon, cloves, fennel, pepper, star anise, and retail 5-spice blend), at 4 levels (0%, 0.1%, 0.5%, and 1.0% of meat weight), 3 storage days (1, 8, and 15 d), and 3 replications of the entire experiment. TBA values (duplicates for each sample) were measured as an indicator of rancidity at 1, 8, and 15 d storage of cooked ground beef at 2 °C.

Treatment means were calculated by analysis of variance (ANOVA) using Statistica™ software (Statsoft Inc, Tulsa, Okla., U.S.A.). Significant differences among means were determined by calculation of Fisher’s least significant difference (LSD) values. Significance was defined at \( P < 0.05 \) for ANOVA and LSD values.

The optimum or lowest effective spice level (0.1%, 0.5%, or 1%) for each individual spice was determined as the lowest spice concentration that resulted in TBA values significantly lower than the controls (0% spice). The 5 spices at their lowest effective levels were mixed to create the low clove 5-spice blend for sensory testing in experiment 2. The low clove 5-spice blend was created because cloves have strong flavor and odor that could be a concern with consumers. Thus, it was desirable to evaluate a blend with a clove proportion lower than 20% (the level if each of the 5 spices were present in equal proportions).

**Experiment 2—Sensory evaluation**

Cooked beef samples made with spices at their lowest effective levels as described in experiment 1 were evaluated for intensity of cooked beef flavor, rancid flavor/odor, and spice flavor intensity. A total of 10 treatments were evaluated (0.5% cinnamon, 0.1% cloves, 0.5% fennel, 0.5% pepper, 0.5% star anise, 0.5% retail 5-spice blend, 0.5% optimal 5-spice blend, rancid control, 0.5% sodium tripolyphosphate (STP) control, fresh control). The rancid control was cooked ground beef without added spices and held 15 d at 2 °C, allowing time to observe the full extent of oxidation in the controls compared with spice-treated samples. The fresh control was cooked ground beef without spices prepared on the day of the panel evaluation. Trained panelists (n = 13) evaluated samples after 15 d of storage at 2 °C. TBA values were measured on the samples that were served to the panelists. Treatment means were calculated by ANOVA as described in experiment 1. Correlation coefficients were calculated among sensory scores and TBA values. Significance was defined at \( P < 0.01 \) for correlation coefficients.

**Experiment 3—Aerobic plate count**

A 10-g portion of ground beef was mixed with 90 mL of sterile peptone water (Difco, Detroit, Mich., U.S.A.) in a dilution bottle, and plate counts were done on serial dilutions of cooked ground beef samples after 1, 8, or 15 d storage at 2 °C, following standard procedures (Messer and others 1978). Standard methods agar (Difco) was used as growth media. Duplicate plates were counted after incubation at 37 °C for 48 h.

**Sample preparation**

Ground star anise, fennel, cloves, and cinnamon (McCormick & Co. Inc., Hunt Valley, Md., U.S.A.), black pepper (Inter-American Foods Inc., Cincinnati, Ohio, U.S.A.), and lean ground beef (15% fat) were purchased at a local grocery. Retail Chinese 5-spice blend (Dynasty, San Francisco, Calif., U.S.A.) was also purchased locally. In addition to the 5 traditional spices, the retail blend also contained ginger and licorice. Each spice was manually mixed with ground beef (100 g/treatment) at 0.1%, 0.5%, and 1.0% levels. Mixed samples were thoroughly cooked at 163 °C for 5 min, to a final temperature of 82 °C to 85 °C, as measured using a VersaTuff Plus 396 digital thermometer (Atkins Technical, Inc, Gainesville, Fla., U.S.A.) with a thin probe for fast response. The cooked ground beef crumbles were placed in resealable plastic bags, cooled for 10 to 15 min at room temperature, and stored for 1, 8, or 15 d at 2 °C. Thiobarbituric acid (TBA) values were measured in duplicate at 1, 8, or 15 d on the cooked samples as an indicator of oxidative rancidity. For each ingredient spice, the experiment was replicated 3 times. Duplicate sample analysis was performed. Thus, there were 6 observations per treatment.

**TBA value**

Thiobarbituric acid-reactive substances (TBARS) assay was performed as described by Bueye and Aust (1978). Duplicate samples (0.5 g) for all the treatments were mixed with 2.5 mL of stock solution containing 0.375% TBA (Sigma Chemical Co., St. Louis, Mo., U.S.A.), 15% TCA (Mallinckrodt Baker Inc., Paris, Ky., U.S.A.), and 0.25 N HCl. The mixture was heated for 10 min in a boiling water bath (100 °C) to develop a pink color, cooled in tap water, and then centrifuged (Sorvall Instruments, Model RC5B, DuPont, Wilmington, Del., U.S.A.) at 4300 g rpm for 10 min. The absorbance of the supernatant was measured spectrophotometrically (Spectronic 21D, Milton Roy, Rochester, N.Y., U.S.A.) at 532 nm against a blank that contained all the reagents except the meat. The malonaldehyde (MDA) concentration was calculated using an extinction coefficient of 1.56 × 10⁵ M/cm for the pink TBA-MDA pigment (Sinnhuber and Yu 1958). The absorbance values were converted to ppm malonaldehyde by using the following equations:

\[
TBA \text{ nr (mg/kg)} = \frac{\text{Sample } A_{532} \times (1 M \text{TBA Chromagen/156000})}{(1 \text{ mole/L} \times M) \times (0.003 L/0.5 g \text{ meat}) \times (72.07 g \text{ MDA/mole MDA}) \times (1000 g/kg)}
\]

(1)

\[
TBA \text{ nr (ppm)} = \text{Sample } A_{532} \times 2.77
\]

(2)

**Sensory evaluation**

All panelists had previous sensory panel experience with cooked beef products. The panelists were trained in 2 sessions. In the 1st session, panelists were familiarized with the 5-point intensity scale and its usage. Panelists were also familiarized with cooked beef flavor (both fresh and rancid samples) and cooked ground beef with individual added spices (cinnamon, cloves, fennel, pepper, and star anise) and Chinese 5-spice blends at low (0.1%) and high (1%) spice concentrations. Group discussion was conducted regarding sample attributes. In the 2nd session, panelists again evaluated the same samples. The most consistent panelists (n = 13) were included in the final sensory panel.

Treatment samples were prepared with spice concentration at lowest effective levels of 0.5% for cinnamon, fennel, star anise, or black pepper, and 0.1% for clove (% raw meat weight) as determined in experiment 1 of this study. The low clove blend was 4.8% by weight cloves and 23.8% each of cinnamon, fennel, pepper, and star anise. Spice treatments were cooked, packaged, and stored as previously described. Three control cooked beef samples were also
Spice antioxidants in ground beef . . .

The 7 treatment samples at optimal concentrations and 3 controls of cooked beef crumbs were evaluated in 3 sessions. A set of 5 or 6 samples (6 g each) was served to each panelist in each session, consisting of 2 or 3 spice-treated samples and 3 controls. Samples were coded and microwave reheated for 25 s to attain a temperature of 80 °C to 85 °C immediately before serving. Samples were evaluated in individual booths under red lights. The serving order was randomized to avoid positional bias.

Panelists were asked to evaluate samples for intensity of rancid odor, rancid flavor, beef flavor, and spice flavor on a 5-point scale, where 1 = no flavor or odor, 2 = slightly intense, 3 = moderately intense, 4 = very intense, and 5 = extremely intense flavor or odor. Panelists were also asked to provide additional qualitative comments for each sample. Before evaluating the next sample, ballot instructions specified that the previous sample be expectorated into cups provided for that purpose. Panelists were instructed to rinse their mouth with tap water. Unsalted crackers were also provided to cleanse the palate.

Results and Discussion

Experiment 1—TBA assay of cooked ground beef with individual spices

Main effects of treatment (cinnamon, cloves, fennel, pepper, star anise, retail 5-spice blend), spice level (0%, 0.1%, 0.5%, 1.0%), and day of refrigerated storage (1, 8, 15 d) significantly affected the TBA values of cooked ground beef (Table 1). All 2-way interactions also affected (P < 0.05) TBA values, but the 3-way interaction of treatment × spice level × day storage did not significantly affect TBA values (Table 1).

Cooked ground beef mean TBA values for the 2-way interaction of spice treatment × level are shown in Table 2. Mean TBA values were high (3.4) for control cooked ground beef samples. With 1% use level, all spice treatments had lower (P < 0.05) TBA values than controls. At the lowest use level of 0.1% of meat weight, all spices except pepper had lower TBA values than controls, and clove treatments had lower (P < 0.05) TBA values than other spices. Mean TBA value for the 0.1% clove treatment was 0.76, compared with 1.66, 2.32, 2.87, and 2.55 for 0.1% cinnamon, fennel, pepper, and star anise, respectively (Table 2).

Thus, the optimum or lowest effective spice level for cloves was 0.1% and 0.5% for the other spices, where lowest effective spice level was defined as the lowest spice weight/100 g meat (0.1, 0.5, or 1.0) that had significantly lower TBA values than other levels (Table 2). After 15 d of refrigerated storage, TBA values were as high as 5.9 for controls without added spice, compared with 0.79, 0.75, 2.22, 1.70, 1.30, and 0.37 for 0.5% cinnamon, 0.1% cloves, 0.5% fennel, 0.5% pepper, 0.5% star anise, and 0.5% 5-spice blend (lowest effective levels, respectively; Figure 1 to 6). TBA values >1.0 are usually associated with rancid flavor/odor by sensory panelists (Tarladgis and others 1960; Jayasingh and Cornforth 2003). Note that TBA values of clove-treated ground beef samples (Figure 2) remained less than 1.0 for the entire 15-d storage period as did the samples with 0.5% or 1.0% retail 5-spice blend (Figure 6). Ground beef with 1.0% fennel or 0.5% to 1.0% pepper had TBA values <1.1 for 8 d storage (Figure 3 and 4). Ground beef with 1.0% cinnamon or 1.0% star anise had TBA values <1.0 for 15 d storage (Figure 1 and 5). Thus, treatment with cloves was clearly the most effective among individual spices for maintenance of low TBA values of cooked ground beef during refrigerated storage.

The antioxidant effects of cinnamon, clove, fennel, pepper, and star anise in this study are in agreement with previous findings by others. Cinnamon essential oil has been shown to have significant antioxidant activity in Chinese-style sausages (Ying and others 1998). Cloves at 0.05% were shown to enhance the storage stability of cooked ground beef formulated with the individual spices of Chinese 5-spice, at use levels of 0.1%, 0.5%, and 1.0% of raw meat weight*.

Table 1—Summary of significance (P < 0.05) as determined by analysis of variance (ANOVA)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>n</th>
<th>TBA</th>
<th>P level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>72</td>
<td>*</td>
<td>0.0001</td>
</tr>
<tr>
<td>Spice Level</td>
<td>108</td>
<td>*</td>
<td>0.0001</td>
</tr>
<tr>
<td>D of storage</td>
<td>144</td>
<td>*</td>
<td>0.0001</td>
</tr>
<tr>
<td>Treatment × level</td>
<td>18</td>
<td>*</td>
<td>0.0001</td>
</tr>
<tr>
<td>Treatment × day</td>
<td>24</td>
<td>*</td>
<td>0.0001</td>
</tr>
<tr>
<td>Level × day</td>
<td>36</td>
<td>*</td>
<td>0.0001</td>
</tr>
<tr>
<td>Treatment × level × day</td>
<td>6</td>
<td>NS</td>
<td>0.1065</td>
</tr>
</tbody>
</table>

*Significant at P < 0.05; NS = not significant at P < 0.05; n = nr observations per mean.

Table 2—Mean thiobarbituric acid (TBA) values* for cooked ground beef formulated with the individual spices of Chinese 5-spice, at use levels of 0.1%, 0.5%, and 1.0% of raw meat weight

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Spice level (% meat wt.)</th>
<th>TBA (ppm MDA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.0</td>
<td>3.41 a</td>
</tr>
<tr>
<td>Cinnamon</td>
<td>0.1</td>
<td>1.66 cd</td>
</tr>
<tr>
<td>Cinnamon</td>
<td>0.5</td>
<td>0.76 e</td>
</tr>
<tr>
<td>Cinnamon</td>
<td>1.0</td>
<td>0.79 e</td>
</tr>
<tr>
<td>Cloves</td>
<td>0.1</td>
<td>0.76 e</td>
</tr>
<tr>
<td>Cloves</td>
<td>0.5</td>
<td>0.96 de</td>
</tr>
<tr>
<td>Cloves</td>
<td>1.0</td>
<td>0.88 e</td>
</tr>
<tr>
<td>Fennel</td>
<td>0.1</td>
<td>2.32 bc</td>
</tr>
<tr>
<td>Fennel</td>
<td>0.5</td>
<td>1.39 de</td>
</tr>
<tr>
<td>Fennel</td>
<td>1.0</td>
<td>0.99 de</td>
</tr>
<tr>
<td>Pepper</td>
<td>0.1</td>
<td>2.87 ab</td>
</tr>
<tr>
<td>Pepper</td>
<td>0.5</td>
<td>1.28 de</td>
</tr>
<tr>
<td>Pepper</td>
<td>1.0</td>
<td>1.26 de</td>
</tr>
<tr>
<td>Star anise</td>
<td>0.1</td>
<td>2.55 b</td>
</tr>
<tr>
<td>Star anise</td>
<td>0.5</td>
<td>0.97 de</td>
</tr>
<tr>
<td>Star anise</td>
<td>1.0</td>
<td>0.71 e</td>
</tr>
<tr>
<td>Retail 5-spice</td>
<td>0.1</td>
<td>0.99 de</td>
</tr>
<tr>
<td>Retail 5-spice</td>
<td>0.5</td>
<td>0.73 de</td>
</tr>
<tr>
<td>Retail 5-spice</td>
<td>1.0</td>
<td>1.00 de</td>
</tr>
<tr>
<td>LSD</td>
<td>0.05</td>
<td>0.76</td>
</tr>
</tbody>
</table>

*Means TBA values with the same letter are not different (P < 0.05).

Means were pooled for storage time (1, 8, and 15 d) after cooking (n = 18).
Spice antioxidants in ground beef... Black pepper was an effective sensory flavoring agent in chicken feet (Jokpyun, a traditional Korean gel type delicacy) at the 0.33% level, based on response surface methodology (Mira and others 2000). Ground black pepper oleoresin extracted by supercritical carbon dioxide was more effective in reducing lipid oxidation of cooked ground pork than oleoresin extracted by conventional methods (Tiprisukond and others 1998). Star anise was effective at 0.5% level based on meat weight. Anise-treated samples had a TBA value of 0.97. Anise has also been shown to have antioxidant effects in Chinese marinated pork shanks as compared with controls (Tzu and others 1997).

Experiment 2—sensory evaluation
Mean trained panel sensory scores and thiobarbituric acid

![Figure 1](image1.png)

Figure 1—Effect of cinnamon concentration (0%, 0.1%, 0.5%, 1.0% of meat wt) on thiobarbituric acid (TBA) values of cooked ground beef during refrigerated storage (ppm MDA = parts per million malonaldehyde). Mean values differing by more than 0.94 are significantly different. LSD_{0.05} = 0.94.

![Figure 2](image2.png)

Figure 2—Effect of clove concentration (0%, 0.1%, 0.5%, 1.0% of meat wt) on thiobarbituric acid (TBA) values of cooked ground beef during refrigerated storage (ppm MDA = parts per million malonaldehyde). LSD_{0.05} = 0.94.

![Figure 3](image3.png)

Figure 3—Effect of ground fennel concentration (0%, 0.1%, 0.5%, 1.0% of meat wt) on thiobarbituric acid (TBA) values of cooked ground beef during refrigerated storage (ppm MDA = parts per million malonaldehyde). LSD_{0.05} = 0.94.

![Figure 4](image4.png)

Figure 4—Effect of pepper concentration (0%, 0.1%, 0.5%, 1.0% of meat wt) on thiobarbituric acid (TBA) values of cooked ground beef during refrigerated storage (ppm MDA = parts per million malonaldehyde). LSD_{0.05} = 0.94.

![Figure 5](image5.png)

Figure 5—Effect of star anise concentration (0%, 0.1%, 0.5%, 1.0% of meat wt) on thiobarbituric acid (TBA) values of cooked ground beef during refrigerated storage (ppm MDA = parts per million malonaldehyde). LSD_{0.05} = 0.94.

![Figure 6](image6.png)

Figure 6—Effect of retail Chinese 5-spice concentration (0%, 0.1%, 0.5%, 1.0% of meat wt) on thiobarbituric acid (TBA) values of cooked ground beef during refrigerated storage (ppm MDA = parts per million malonaldehyde). LSD_{0.05} = 0.94.
Spice antioxidants in ground beef...

Table 3—Mean trained panel sensory scores and thiobarbituric acid (TBA) values of spice-treated, cooked ground beef crumbles after 15 d storage at 2 °C. Lowest effective spice levels were used as determined from Table 1.*

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Use level (%) meat weight</th>
<th>Rancid odor</th>
<th>Rancid flavor</th>
<th>Beef flavor</th>
<th>Spice flavor</th>
<th>TBA value</th>
<th>Qualitative comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rancid control</td>
<td>0.0</td>
<td>3.3 a</td>
<td>3.4 a</td>
<td>2.0 b</td>
<td>1.0 d</td>
<td>7.2 a</td>
<td>Rancid, painty, stale</td>
</tr>
<tr>
<td>STP control</td>
<td>0.5</td>
<td>1.4 b</td>
<td>1.4 b</td>
<td>3.0 a</td>
<td>1.1 d</td>
<td>0.3 f</td>
<td>Beery, salty</td>
</tr>
<tr>
<td>Fresh control</td>
<td>0.0</td>
<td>1.5 b</td>
<td>1.5 b</td>
<td>3.2 a</td>
<td>1.1 d</td>
<td>1.0 de</td>
<td>Steak-like, oily, beefy</td>
</tr>
<tr>
<td>Cinnamon</td>
<td>0.5</td>
<td>1.1 b</td>
<td>1.1 b</td>
<td>1.7 b</td>
<td>2.9 bc</td>
<td>1.6 cd</td>
<td>Cinnamon flavor, spicy</td>
</tr>
<tr>
<td>Cloves</td>
<td>0.1</td>
<td>1.0 b</td>
<td>1.1 b</td>
<td>2.2 b</td>
<td>3.1 bc</td>
<td>0.4 e</td>
<td>Strong clove flavor, smells like dentist’s office</td>
</tr>
<tr>
<td>Fennel</td>
<td>0.5</td>
<td>1.5 b</td>
<td>1.6 b</td>
<td>1.9 b</td>
<td>3.1 bc</td>
<td>5.5 b</td>
<td>Licorice flavor, spicy</td>
</tr>
<tr>
<td>Pepper</td>
<td>0.5</td>
<td>1.4 b</td>
<td>1.2 b</td>
<td>2.1 b</td>
<td>3.2 ab</td>
<td>1.6 cd</td>
<td>Peppery, hot</td>
</tr>
<tr>
<td>Star anise</td>
<td>0.5</td>
<td>1.2 b</td>
<td>1.1 b</td>
<td>1.8 b</td>
<td>3.9 a</td>
<td>1.9 c</td>
<td>Licorice flavor, spicy</td>
</tr>
<tr>
<td>Retail 5-spice blend</td>
<td>0.5</td>
<td>1.0 b</td>
<td>1.2 b</td>
<td>1.9 b</td>
<td>3.3 ab</td>
<td>0.7 ef</td>
<td>Strong spicy, black licorice</td>
</tr>
<tr>
<td>Low clove-spice blend</td>
<td>0.5</td>
<td>1.3 b</td>
<td>1.2 b</td>
<td>2.1 b</td>
<td>2.4 c</td>
<td>1.0 de</td>
<td>Spicy</td>
</tr>
<tr>
<td>LSD</td>
<td>0.5</td>
<td>0.52</td>
<td>0.52</td>
<td>0.68</td>
<td>0.74</td>
<td>0.66</td>
<td></td>
</tr>
</tbody>
</table>

*Mean values within a column with the same letter are not different (P < 0.05)

Table 4—Correlation coefficients (r) among mean trained panel sensory scores and thiobarbituric acid (TBA) values of spice-treated, cooked ground beef crumbles after 15 d storage at 2 °C

<table>
<thead>
<tr>
<th>Sensory score</th>
<th>Rancid odor</th>
<th>Rancid flavor</th>
<th>Beef flavor</th>
<th>Spice flavor</th>
<th>TBA value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rancid odor</td>
<td>1.00</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Rancid flavor</td>
<td>0.98*</td>
<td>1.00</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Beef flavor</td>
<td>0.03</td>
<td>0.05</td>
<td>1.00</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Spice flavor</td>
<td>−0.57*</td>
<td>−0.61*</td>
<td>−0.60*</td>
<td>1.00</td>
<td>—</td>
</tr>
<tr>
<td>TBA value</td>
<td>0.83*</td>
<td>0.78*</td>
<td>−0.31</td>
<td>−0.21</td>
<td>1.00</td>
</tr>
</tbody>
</table>

*P < 0.01.

In this study, the trained panel provided precise information on intensity of various flavors, with no indication of acceptability. One may infer, however, that samples with high scores for rancid flavor would be unacceptable to most consumers. Conversely, samples with moderate spice flavor intensity would be acceptable to many people. Some panelists commented that some samples were “too hot” or “too spicy,” indicating a dislike for higher spice levels (Table 3).

Correlation coefficients among mean trained panel sensory scores and thiobarbituric acid (TBA) values of spice-treated, cooked ground beef crumbles are shown in Table 4. There was a high correlation (P < 0.01) between TBA values and panel scores for rancid odor and flavor (0.83 and 0.78, respectively). Not surprisingly, a very high correlation (0.98) was observed between rancid flavor and rancid odor. There was a significant inverse relationship between spice flavor and beef flavor, indicating that samples with added spice did not retain a typical cooked ground beef flavor. Spice flavor was inversely correlated (P < 0.01) with rancid odor and flavor (−0.57 and −0.61, respectively). Thus, samples with added spice tended to lose their beef flavor but did not taste rancid.

Experiment 3—aerobic plate count

Aerobic plate counts were done after 1, 8, or 15 d of storage at 1 °C of cooked ground beef samples made with 0.5% retail 5-spice, 0.5% optimum 5-spice, or controls without spice. Log10 mean aerobic plate counts pooled over storage time were 4.1, 4.1, and 3.9, respectively, and were not significantly different, which is not unusual for cooked samples. There were no significant treatment x time interactions for aerobic plate counts. Thus, addition of 0.5% spice blends had no antimicrobial effects during storage of cooked ground beef in this study. Spices and essential oils are known to...
exhibit antimicrobial effects in various food products or model systems. (Yuste and Fung 2002; Guayot and others 2003; Ozkan and others 2003). The lack of antimicrobial effects in cooked ground beef during storage in this study may be due to heat inactivation or loss of antimicrobial components during cooking.

**Conclusions**

All spices imparted a distinctive flavor to the cooked ground beef and had marked antioxidant properties. These traditional spices do not simply mask the rancid off-flavors but rather have antioxidant effects.

**Acknowledgments**

The authors gratefully acknowledge the financial support of the Utah Agricultural Experiment Station in support of this study. Utah Agricultural Experiment Station journal paper nr 7651.

**References**


